Jabez Hogg-Esqr.
with kind regards -

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AND

RECORD OF HISTOLOGICAL RESEARCH

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THE MONTHLY MICROSCOPICAL JOURNAL:

TRANSACTIONS OF THE ROYAL MICROSCOPICAL SOCIETY,

AND

RECORD OF HISTOLOGICAL RESEARCH.

EDITED BY HENRY LAWSON, M.D., F.R.M.S.,
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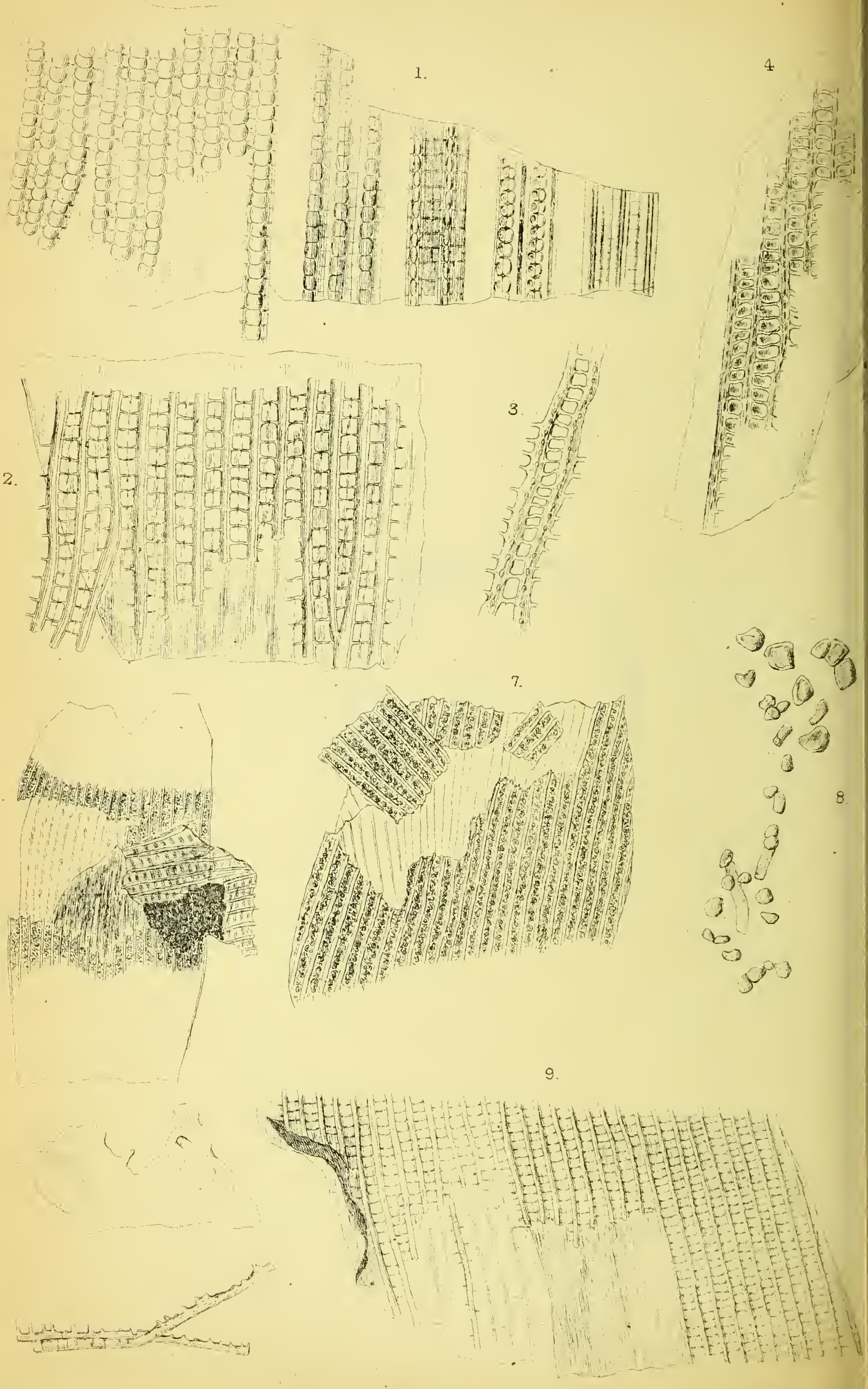

Lepidoptera Scales & fragments.

Tuffen West sc.
W. West & C°

II.—*Remarks on the General and Particular Construction of the Scales of some of the Lepidoptera, as bearing on the Structure of the "Test Scale" of Lepidocyrtus curvicollis.* By R. L. Maddox, M.D.

(*Read before the* Royal Microscopical Society, *May* 3, 1871.)

The investigation of the intimate structure of some minute objects with which the microscopist is quite familiar, whether for the purpose of demonstrating their integral beauty and exquisite design, or for exhibiting and testing the optician's skill, is a source so replete with difficulty, that the opinions of trustworthy observers are pre-

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EXPLANATION OF PLATES LXXXVI., LXXXVII., and LXXXVIII.

Lepidoptera Scales and Fragments.

Fig. 1.—Part of a China butterfly scale—*Tanonia Œnone*, Ind. China—showing the outer transparent membrane: to the left, a beaded appearance of the framework, out of focus; to the right, various chromatic effects induced by change of focus and direction of the incident light. × 1600.

„ 2.—The same portion of the scale, showing the structural framework of the ribs and transverse bars, × 1600.

„ 3.—Part of the same scale seen reversed, indicating on the ribs what is believed to be the vertical attachments to the outer or middle membrane when three exist, × 1600.

„ 4.—Part of another scale of the same insect, showing the outer membrane and the framework with chromatic interference and pseudo-beading, × 1600.

„ 5.—Part of a large yellowish-white scale from a China butterfly wing—*Papilio Erithonius* (Cram.), Ind. China. At one side is seen the violent chromatic effect of interference caused by the longitudinal ribs and oblique attachments—"striæ"; also the markings of the transverse bars on the (middle or?) outer membrane, for it appears to consist of two layers. × 1000.

„ 6.—An injured dark scale from *P. Erithonius* (Cram.), Ind. China, with a portion of the inner pigmentary membrane turned over, and the middle showing the vertical attachments of the ribs, and the outer membrane, × 1000.

„ 7.—An injured dull-grey scale from the same butterfly, indicating the inner ribbed membrane with its pale, granular, pigmentary deposit, and the oblique framing of the middle or outer layer ("striæ"), × 1000.

„ 8.—Irregular fragments of the external pigmentary deposit from a dark scale of *P. Erithonius*, × 1000.

„ 9.—Part of a scale from the wing of the same butterfly as Fig. 1, showing three membranes—the outer, the middle retaining a part of the framework, and the inner with the heavier portion: also two fragments; outer membrane, *a*; ribs, *b*. × 950.

„ 10.—Fragment of a foreign butterfly scale, received from Mr. McIntire (upper surface of wing and scale), showing the membrane and delicate framework, with indications of a beaded appearance due to thickening at the junctions of the bars and ribs, × 1600.

„ 11.—Fragment of a scale from the same insect, showing a marked pseudo-beaded appearance in the ribs. *The scale is remarkably free of pigment.* × 1600.

„ 12.—Part of a scale from the same butterfly (under surface of wing, upper surface of scale). The transverse bars are rare, except at the edge; the longitudinal ribs, which show the supposed vertical attachments at one or both sides of several, producing when in place the pseudo-beaded appearance, well seen in the rib. × 1600. [Fig. 13.

ferred rather than undertake the examination for ourselves; or else we are disposed to rest satisfied with their general aspects.

Occasionally, however, startled by something overlooked, or by new and imposing views, there is risk of being carried away by the stream of novelty while waiting for extended evidence. Hence

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Fig. 13.—Fragment of a scale of an Indian butterfly—*Terias Hecuba*, Ind. China—slightly charred, showing the outer framework and membrane, × 1600.

„ 14.—Beaded chromatic appearance of part of Fig. 17, well charred, × 1600.

„ 15.—Part of the same scale as Fig. 18, showing the longitudinal ribs, the transverse bars and the oblique attachments, which give rise to the marked wavy "Test scale" aspect. This figure has been roughly enlarged for showing artificially the production of beads by interference.—*Vide* photographs. × 1600.

„ 16.—The direction of the incident light altered, the scale now furnishing the pseudo-beaded appearance at the junctions and interspaces, × 1600.

„ 17.—A torrefied scale from the body of the same insect, *T. Hecuba*, showing a marked resemblance to some of the scales of *Lepidocyrtus curvicollis*, × 500.

„ 18.—A long scale from the body of the same butterfly, well charred, showing the "notes" and transverse bars ("striæ") simulating the "Test scale," × 500.

„ 19.—A body scale from the same insect still more torrefied, throwing the longitudinal ribs into somewhat irregular lines, very much resembling Mr. McIntire's figure, Dr. Woodward's and my own photographs of *Degeeria domestica* (*Seira domestica*, Lubbock), × 500.

„ 20.—A scale highly iridescent and of some substance from near the shoulder of the wing of the large China moth (? *Attacus cynthia*), × 230.

„ 21.—A portion of the same scale, showing pseudo-beads in the longitudinal ribs and interspaces, × 1000.

„ 22.—From the same scale near the tip, showing the framework and membranes, × 1000.

„ 23.—A fragment from a similar scale of the large China moth producing two sets of pseudo-beads, one on either side of the long rib, with a dark shadow on one side, × 1000.

„ 24.—The same portion of the scale as Fig. 23, showing the framework of longitudinal ribs and transverse bars, × 1000.

„ 25.—A fragment of a scale from the wing of the same moth, showing the inner membrane and pigmentary deposit, the transverse bars ("striæ") and (middle or) outer membrane with a portion of the oblique attachments, × 2625.

(On some scales the pigment layer apparently covered the transverse bars.)

„ 26.—A coarse scale of *Lepidocyrtus curvicollis*, seen under different aspects.

a, The under surface, first ocus, showing the longitudinal ribs somewhat bent and depressed, marked faintly with transverse markings.

b, The same focussed rather more deeply, producing the beaded appearance of the rib.

c, The same part, the focus carried a little deeper, giving rise to apparently elongated depressions, with the shadows on the same side as in *a*.

d, The same portion under a still deeper focus, producing a dark, cellular arrangement with bright edges.

The illumination remained unchanged in these four figures.

e, The scale, incident light and focus altered from *a*, *b*, *c*, *d*, producing the bent, short, clumsy, pin appearance, slightly marked, and with a greenish shadow on one side, resting apparently on a dark-grey membrane, the points of the pins shading off obliquely. (*Vide* Pl. XXXVII., Fig. 5, of Mr. McIntire's *Templetonia nitida*, 'M. M. J.')

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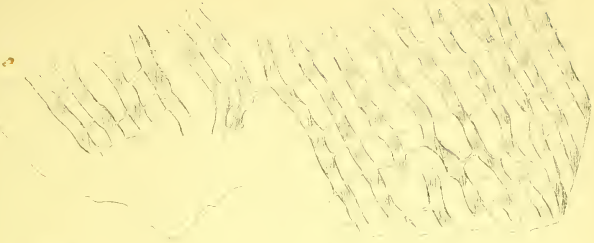

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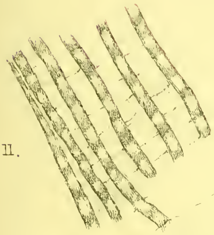

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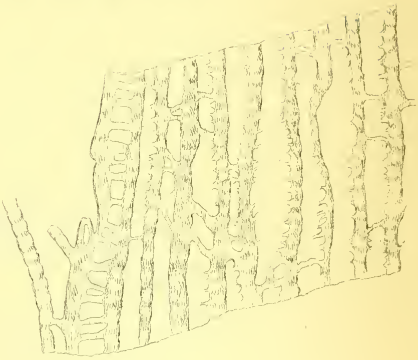

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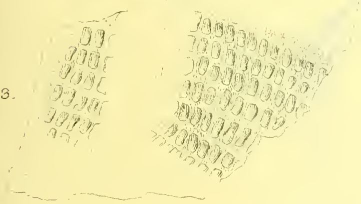

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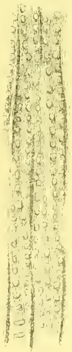

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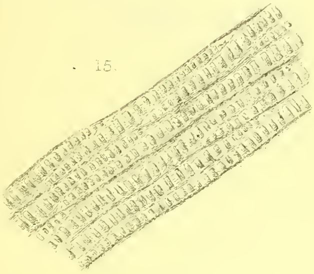

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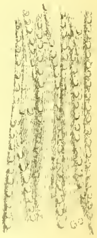

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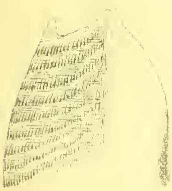

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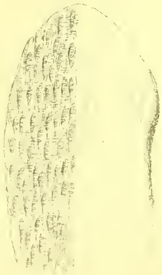

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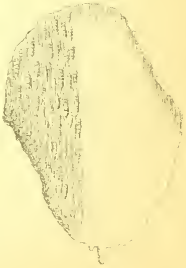

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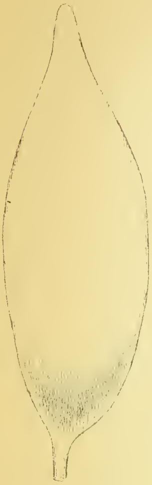

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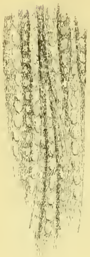

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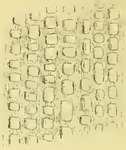

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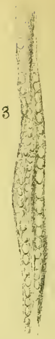

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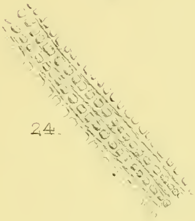

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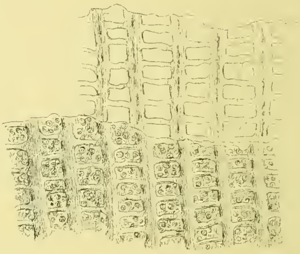

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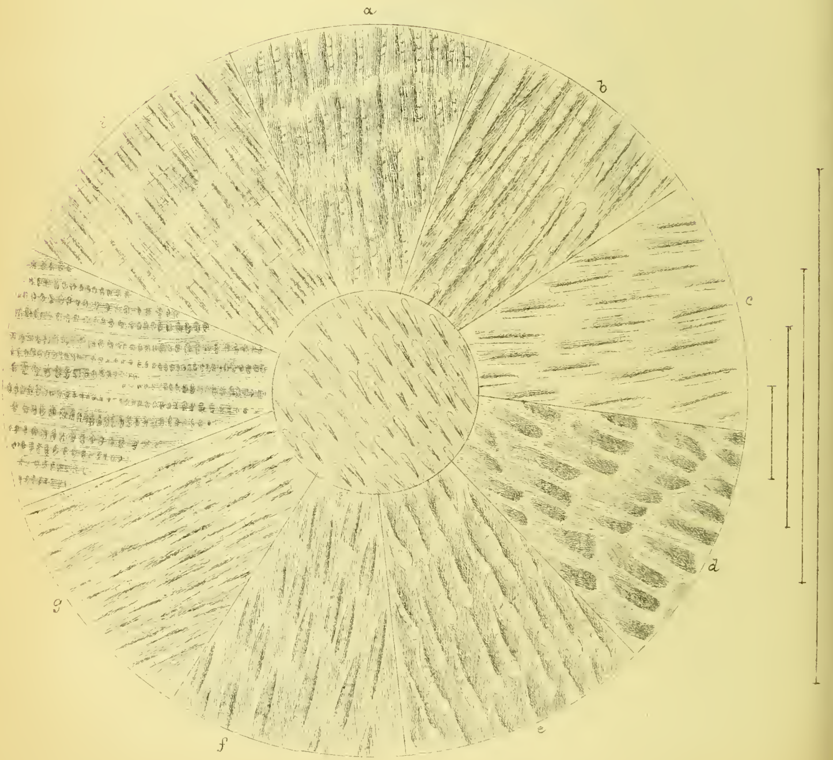

Lepidoptera Scales & fragments

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caution is especially necessary ere embracing new opinions on the structure of minute more or less transparent bodies, however refined may have been the method of investigation, if they be not fully supported by analogy in objects of the same nature, which permit of more easy examination, and certainly it becomes imperative when fresh research tends to opposite conclusions.

By these preliminary remarks it is not intended to convey the idea anyone should remain satisfied with the knowledge already gained, but simply not to be too ready to accept evidence on a scanty basis which for various reasons is open to considerable doubt.

All acknowledge the manifold difficulties that supervene on attempting to decide the structural nature of minute transparent objects, when they are replete with optical effects, resulting from the transmission of light, at varying angles, through irregular surfaces

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f, The focus, only, altered, giving rise to dark, elongated areas—"notes," supported on a pale membrane marked transversely; the heads not rounded, but somewhat acute at one corner, very like the appearance figured in 'Quekett on the Microscope,' plate viii., fig. 4, *a*; and some of the notes in Dr. Woodward's photographs just received.

g, The position of the scale and incident light altered; an appearance approaching the first focus, but with two dark shadows, interrupted, either side of the long rib; the transverse markings still seen.

i, The scale and direction of the light slightly changed, furnishing dark shadows and highly chromatic effects (seen in the coloured drawing), with universal faint striation.

h, The appearance of a framework similar to the Lepidoptera scales, seen with difficulty, and when the light is not thrown sufficiently obliquely to produce colour—all magnified 2625 diam.

The central portion of the figure gives the optician's view, but showing oblique lines faintly.

[The remaining figures refer to some exquisite photographs and figures which have been placed by Dr. Maddox in the Society's Collection.—Ed. 'M. M. J.']

FIG. 27.—A photograph of interference image of Fig. 31, produced by artificial means; simulating beads. vide p: 266.

„ 28.—A photograph of the same artificial construction, using ¼ plate lenses; simulating *Degeeria domestica* scale.

„ 29.—A photograph furnishing bright beaded spots, dark shadow and coalescence of the ribs.

„ 30.—A photograph showing faintly to the left (very distinctly in the negative) a chain of dots (? beads) and the general image as a composed or intermediate one between Figs. 28 and 29.

„ 31.—The rough pencil sketch of Fig. 15, used to construct the artificial framing.

„ 32.—Pencil sketch of injured scale of Humming-bird Sphinx (recent).

- *a*, The edge bars are rubbed into wavy lines.
- *b*, The external coat removed.
- *c*, The little round particles of which the coat consists are rubbed into a confused mass.
- *d*, The surface seen in its natural state; the round particles are most clearly seen on the bars, but they entirely cover the surface.
- *e*, The quill is seen as a hollow tube.

(Fig. and description by Dr. A. Southby, Italy.)

of different thicknesses and refractive powers, or internally stopped, reflected or dispersed. The more the structure retains this characteristic, the greater the difficulty to traverse with confidence the shoals of conjecture.

In venturing to bring before the notice of the Fellows of the Royal Microscopical Society, the subject of the general and particular construction of some of the scales of the Lepidoptera, after the recent and valuable contributions by Mr. McIntire, Mr. Jos. Beck, Mr. Wenham, and Dr. Woodward, as well as the very interesting article by one of your secretaries, Mr. Slack, contributed to the pages of 'The Student,' No. 1, February, 1870, some apology is necessary; but the minute construction of the scales of the Lepidoptera being, so far as I can judge, still open to inquiry, and the subject so full of interest in reference to the views advanced by Dr. Pigott, &c., let me ask your indulgence to be permitted to lay before you the results of a careful, if not very extended, examination, accompanied by coloured drawings of such portions as touch upon the question of beads or beaded structure, as well as the general arrangement of parts in relation to the same, in the "Test scale" of Lepidocyrtus.

If these researches have led me to differ from some authorities in various particulars, the results are stated with diffidence, and with the desire further observations may be undertaken by those far more able than myself to compass the inquiry; but if the evidence can, in any way, tend to place the subject in a more satisfactory condition, or increase the testimony of others, it will amply repay for the trouble and time it has taken. Mr. Slack in the before-mentioned pages of 'The Student' has furnished the opinions of many observers: not to lengthen unnecessarily this article, I shall allude but briefly to them in passing, and refer to his pages for particulars.

The announcement made by Dr. Pigott, in the pages of the Society's Journal for December, 1869, on the structure of the Podura scale, "Test scale," *Lepidocyrtus curvicollis*,* took many of us by surprise—and naturally so, considering this scale to have for years been so continually under observation, and the special study of that accurate observer and artist, the late Richard Beck; therefore to him our thanks are due for rousing us from our wonted apathy, and for pointing out fresh methods for obtaining increased magnification, claiming some advantages over high-power objectives and deep eye-pieces.

To such a contrivance he has given the name "Aplanatic Searcher," and by its means has obtained results which abound with interest; though, to the minds of many observers, they are received with considerable doubt, or referred to optical effects of an illusory nature.

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* *Vide* p. 300.

Unfortunately, the information regarding the structure of the optical part of the instrument is of such a conservative character, both in the original paper, published in the 'Philosophical Transactions,' and in the 'Journal of the Royal Microscopical Society,' that it does not furnish data sufficient for its perfect construction; and as it appears to have resulted from "error and trial" rather than from computation, hence one reason why others may not be as successful as he appears to have been. I can well understand the tediousness of the research and the patience necessitated to bring such a method to so successful a phase, without losing definition. Doubtless it will stimulate both opticians and amateurs to renewed efforts to cover the "residuary aberration"; but if we do not also get rid of the secondary spectrum, there is something more to be achieved than is yet accomplished. Possibly some refracting cement, as Mr. Grove's purified resin and castor-oil, or Canada balsam and castor-oil, if made one of the components of an achromatic "concave" or "corrector," may furnish some help.

By no means do I wish to detract from the advantages of the "aplanatic searcher" in other hands, but in mine it did not fulfil the expectations entertained. It certainly furnished great facility for bringing out colour in lined objects of different refractive power, and thus perhaps it may have a wide claim to our favour, *provided* we are not carried away by the influence, by reason, as Mr. McIntire so aptly expresses it in his note of Jan. 20, which I take the liberty to quote, that "the colour invests some objects with a new charm." It was not found to increase the defining power of the objective, but this may have been due to want of ability on my part.

It seemed questionable whether three "over-corrected" bodies, compound lenses, eye-pieces, searcher, and objective,* and the additional over-correction furnished by the thin covering glass, would provide, by one traversing between the two others, perfect achromatism.

It may perhaps be as well to point out the error in the original paper, 'Phil. Trans.,' and the appended note in p. 129, where, in the definition of the aberrations, positive and negative aberration have been confounded. The same error is repeated in the present 'Quart. Journal of Micros. Science,' evidently having escaped the notice of the author.

Whatever may be its value as regards depth of focus, &c., of this I feel confident, that at the same time that it furnishes a very ready means for increased amplification, so it also facilitates optical errors in observations. The limitation as relates to light, the length of tube needed, though inconvenient, are quite, if not more than, balanced by the erect image and the use of low powers and eye-pieces instead of high ones. The depth of focus, in many ways, is very valuable, yet when oblique light is employed, *and the object develops colour*, is a constant source of danger to correct interpretation of structure. This, it is believed, will be acknowledged by those accustomed to examine objects structurally.

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* *Vide* editorial remarks on Dr. Pigott's paper in the 'Phil. Trans.,' in the 'M. M. J.,' No. XXVII., p. 129.

When more is learnt of its optical combinations, or some secure method discovered for furnishing a combination as "corrector" and "amplifier," we shall all feel deeply thankful to Dr. Pigott that the employment, long since adopted and rejected by opticians, of intervening lenses, has found a permanent place in the addenda to the ordinary instrument.

The object of this paper being to deal with the general and particular structure of Lepidoptera scales, and their relationship to the structure of the "Test scale," the "aplanatic searcher" would not have been alluded to, had not some of the observations and drawings been made with the form found by "error and trial" convenient, *viz.* a triple and double achromatic, adapted to the proper searcher, racked tube, and employed with a Gundlach's immersion No. 7^a ($\frac{1}{16}$th), Wales' $\frac{1}{8}$th, and Smith and Beck's $\frac{1}{5}$th, with a No. 1 eye-piece and the equilateral prism, proposed by your much-esteemed late President, used with a *bright* north daylight, without achromatic condenser, except for the central portion of the Fig. 26—the object being to simplify as much as possible the mode of observation.

All extraneous light was shut off from the object by a limiting aperture in a thin brass slide, on which the objects between two thin covers, for reversal, were fixed by springs attached to the support; or if the object were on one of the ordinary slides, it was surrounded by an opaque ring or slit, besides other precautions alluded to farther on.

After describing the general appearance with low powers, the waviness of the scale according to the illumination giving place to "*ribbing*, shaded very darkly," &c., Dr. Pigott states,* "with 1200 these ribs have divided themselves into a string of longitudinal beads. But with 2300 they appear to lie in the same plane, and terminate abruptly on the basic membrane. Upon focussing for the strings of beads attached to the lower side, the beading appears in the intercostal spaces." Also, with "more oblique, yet achromatic" illumination, "the intervening spaces showing fine traces of intersecting lines."

Now, if these remarks be understood correctly, the structure of the "Test scale" would be as if composed of a (flat) membrane having on each side rows of beads external to its surfaces; rows of beads longitudinal on the one surface and oblique on the other. Again, "synthetically," the same observer finds proofs of his views in the "finest and most transparent scales of 'azure blue,'" hence we must consider, whatever be the true structure of the "Test scale," the Lepidoptera scale is of the same nature. This admitted, it becomes easy to show that the Lepidoptera scale, though furnishing more or less all the optical appearances of the "Test scale," is in reality not constructed after this method. Thus a doubt is at once raised as to the correctness of the view entertained of the structure of the scale of *Lepidocyrtus curvicollis*, and its congeners.

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* P. 300, No. XII., 1869.

Before touching the microscopical investigation of the Lepidoptera scale, it may be as well to ask if we have in any dermic structure of the animal series one composed of beads lying either side of a basic membrane? I know of none, though of course it does not follow such may not exist; therefore these remarks are open to correction. But what possibly is the function of so elaborate a structure as found in the scales of the Lepidoptera and Thysanuradeæ generally?

Surely little can be founded on such a beaded structure, whether for *strength* in the arrangements, or function, beyond a covering and the power to intensify their iris hues; though if we admit that the generally-received opinion respecting the scale of the Lepidoptera is more correct, as I shall show farther on, then by the substitution of a true framework for beads, we obtain strength, and from its position may eventually find some greater purpose to be effected in the economy, beyond contributing to those wonderful iridescent qualities and common tegumentary relations; and which, possibly, is one effecting a change in their semi-fluids by the action of the external air through delicate investing membranes.

All recent scales that have been examined gave more or less evidence of containing some greasy semi-solid material within the membranes; and possibly it will be found the more the body of the bearer partakes of this fatty nature, the more also the scales participate. Such seems to be the case in the large fatty-bodied moths. This, doubtless, largely facilitates the resistance to wet, which in the case of the Lepidoptera would otherwise be almost fatal to their flight.

In my micro-chemical investigations of some of the common butterfly scales, and which Mr. McIntire did me the honour to insert as a note to his paper "On the Minute Structure of the Scales of certain Insects,"* it was found the contents of the scale could be in part removed by various solvents. In addition to those experiments, to which reference is made, strong sulphuric and nitric acids, &c., have been tried, with the hope of obtaining better characteristics of the internal structure; but perhaps the most satisfactory plan has been to *char* the scales,—a suggestion taken from one of my friend Mr. Wenham's letters, to hand some time since, when speaking of the structure of the "Test scale," and to which he alludes in his remarks on that object in the 'M. M. Journal,' No. XXI., p. 124, but which happy idea he had not, it appears, then carried out, for want of the coarse scales; but I learn from him, April 6, that he has done so since with much success.* This will claim notice farther on.

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* 'M. M. Journal,' No. XXV., p. 3.

Hitherto, with the generality of observers, I had regarded the scales of the Lepidoptera as composed of two distinct membranes with their longitudinal ribs (often showing a very beaded look) and cross-bars; but in addition considered these parts, which have been rather too vaguely defined, formed a framework of union between themselves and the membranes, converting the interspace into more or less minute areas, and hence falling towards Dr. Bowerbank's views, though somewhat differing from them in one or two particulars. He makes them to consist of three distinct layers, *viz.* "the upper membrane, which contains the colouring matter; the striæ, which constitute the frame; the under membrane, which is nearly colourless; and finally, the ribs, which are in reality tubes." Where we are at variance will be seen when the special relations of the parts are considered. It has been only after much trouble I could find a solution to the many appearances, old and new (*i. e.* with aplanatic searcher), in conformity with such arrangement. It was at last to injured, dried and charred specimens more particularly, attention was directed. Without detailing the trouble in attempting to break up scales in particular directions—in fact, to dissect them in various ways, and for convenience—the following remarks will apply to scales of two common characters—though not naturally divided, for some scales partake of both, *viz.* the simple and the wavy scale—derived from their appearance under low powers.

The simple scale, as alluded to by others—as Quekett, De la Rue, Dujardin, Carpenter, Beck, Gosse, Slack, McIntire, &c.—is undoubtedly composed of two or more membranes. The outer, as so beautifully shown by Mr. Jos. Beck's simple experiment,† on Thysanuradeæ scales, and which he kindly made before me, and enabled me to repeat myself, is composed of an almost structureless membrane (Dr. Bowerbank's under membrane?), in most scales exceedingly thin and transparent, in others thicker and coloured (possibly capable of being split into two layers or laminæ, though I have only met with a few examples, and these might have consisted of three distinct membranes), occasionally marked on the inner surface with faint indications of attachments of the opposite surface of the ribs and bars, or of oblique lines, "striæ" of others, and sometimes containing fine pigment granules (Fig. 9).

The inner one, as made up of a coarser and darker material, with also pigmentary deposit, in the substance of which the framework of the longitudinal ribs is fixed, projecting somewhat on the free surface, and in which the minute cross-bars running between the longitudinal ones at right angles are imbedded, projecting on the surface of the membrane facing the opposite one—the "transverse striæ" of others (Fig. 6); but besides this, the longitudinal ribs especially, if not the cross-bars, appear to be attached to the opposing surface of the outer or next membrane—if three, by minute more or less wider or narrower vertical projections or septa (Fig. 12); so that the ribs are bound to each other by cross-bars, and to the opposite membrane by short columns or attachments at very different points; hence, where these draw the two surfaces of the scale so closely together, that they are virtually in contact, a depression at that point occurs in the rib, giving it a lobed, if not twisted appearance, and much increasing the difficulty to separate the membranes from each other. Where they alternate to either side of the long rib, giving it a furrowed figure, and the scale is illuminated in a particular direction, the rib seems irregularly bent, and on either side, a little to the right or left, we see the illusory appearance of a twin row of beads, caused by the vertical partitions or framing *at the junctions*, refracting the light at those points more than at the adjoining; whilst a trifling alteration made in the direction of the illuminating pencil divides the rib itself between those rows, and one or two sharp dark shadows start out on either side of the rib, according to focus, and possibly caused by interference (Figs. 23–26). The transverse bars are most likely also slightly attached by their under surfaces to the opposing membrane where we have indications of a beaded character under ordinary observation; at any rate, the spaces embraced between them are occasionally indicated on the opposite surface under some conditions of the incident light (Fig. 5); or they appear capable of being split (Fig. 9).

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* Now published, *vide* 'M. M. Journal,' No. XXIX., p. 216.

† 'M. M. Journal,' No. XXIII., p. 253.

In the wavy scales the same parts exist; but instead of the vertical attachments being only close on either side of the long rib alternately right and left, and those of the transverse bars, the attachment takes place also obliquely across the scale, from the quill both sides towards the centre, and maps out the interval between the ribs into rhomboidal areas or beads, according to the illumination, and which are under other positions, &c., nevertheless seen crossed by the minute transverse bars belonging to the longitudinal framing (Figs. 15, 16).

When the membranes of the scale so attached can be separated, the lines of junction on the opposing surface of the opposite membrane are easily seen in some, and give the ordinary appearance of faint yet bright lines, or ribs, or bars, resting on that membrane, at varying angles in relation to the length of the scale (Fig. 7);

and where the attachment has also taken place beneath the longitudinal rib, often a corresponding interval is noted, so that the oblique markings appear to follow one another in a series of broken lines: sometimes the lines or streaks seem to pass towards the central rib, as though no union had taken place when crossing the long and transverse bars, though this is rarely the case. The long ribs have a somewhat puckered look at those oblique junctions (Fig. 19). In many scales the strong portions of the framework contract towards each other, or no longer continue a parallel course; and where the rib gets a strongly-twisted look, supposed to be due to the vertical partitions, a strong shadow is cast on one or other side, according to the incident light and position of the scale, the rib itself seeming to shade off towards the oblique attachments. If the transverse bars be continued, as it were, far into the substance of the long rib, they give a markedly beaded arrangement.

It is here, I think, we get a clue to the construction of the "Test scale." For a very fine example of this object, I am greatly indebted to the kindness of Mr. McIntire, and from which slide the drawings on Fig. 26 have been made, in the following order, after carefully studying different scales.

The Lepidocyrtus scale, in the strongly-marked examples, when first focussed upon at its inner surface with high powers, shows according to the illumination a series of ribs as stated by the late Richard Beck, more or less continuous in their length, with faint cross striæ, first directly pointed out, I believe, by Dr. Pigott (Fig. 26, *a*); the ribs seem bent somewhat to one or other side, due it is considered to the vertical attachments, so getting depressed and rather twisted or narrowed as they emerge on either side, towards what is seen to be with other illumination the oblique junctions ("striæ") to the transparent membrane, assuming an outer and inner membrane at least to exist; while these form, as it were, a broken or interrupted septum between them, and thus being repeated at the opposite side of the rib, but at a higher or lower position, we get the boundary of the opposite ends, so as to embrace the heads of what at a little deeper focus forms an elongated, more highly refracting part of the scale, in which the transverse markings, which correspond to the transverse bars of the Lepidoptera scale, are readily seen, and forcibly figured by Dr. Pigott (*vide* Fig. 26, *b*). The fine transverse "striæ" which appear at the first focus, I am inclined to regard as arising from the refractions occasioned at the junctions of the vertical septa, and where these alternate to right and left, they give rise, as in some examples of the Lepidoptera scale (Fig. 23), to a doubly-beaded appearance of the rib, with a dark intervening shadow, seen under another focus and direction of the incident light, as at *i*, Fig. 26.

Still deepening the focus but retaining the same illumination as in *a*, *b*, the refracting portions of the ribs appear like elongated depressions, *c*, having the shadows brought to the same side as in *a*. Again deepening the focus *without any other change*, the elongated depressed areas seem to interrupt the light in every direction, except at their edges and oblique junctions, and thus map out the surface into illusory dark cells with light borders, *d*.

Changing the position of the scale and incident light, we find the rib more highly refracting the light at one end than the other, furnishing the appearance of a clumsily-made bent pin, with faint transverse markings still visible, *e*. The knobbed look is undoubtedly due, in part, to the rib being rather more elevated there than in the other portions of its course, and corresponds to Mr. Wenham's figure,* which is very truthful when an oblique view can be obtained of the scale, and to the knobbed appearance of the notes in Dr. Woodward's magnificent photographs; also in Mr. McIntire's figure of *Templetonia nitida*.†

The interruption of the points of the pins seems to be chiefly due to the depression of the rib at those parts from closer contact with the opposite membrane, causing it also to bend a little off to one side.

Retaining the illumination, but deepening the focus, we produce the figure *f*, still showing the transverse markings, the shape closely corresponding with the figure 4 *a*, × 1250, pl. 7, engraved in Quekett's work on the Microscope, second edition, where it will be noticed the heads of the "notes" are rather notched than rounded, as likewise with very many of the "notes" in the beautiful recent photographs, No. 346, new series, by Dr. Woodward, of the "Test scale," × 3200, received from him the 7th of this month (April), and to whom I feel deeply indebted for the charming picture; also for a stereoscopic picture of the same scale, to hand somewhat later. Although I can easily combine most stereoscopic pictures without the use of any stereoscope, I find it difficult to converge the eyes sufficiently to close these images perfectly, yet when obtained, though the "notes" form somewhat elevated areas above the other surface, they have not the appearance of solidity one would at first sight have expected; but this leads me still more to hold the opinion that their production is an optical effect and not the structural arrangement. The photo-micrographs are wonderful results of skill in focussing the two different views, which scarcely depart perhaps sufficiently from the optician's view,—to furnish a strong stereoscopic image of the structure. The shadows also are more on one side, and the central light is long and narrow.

Still shifting the direction of the scale and the illuminating rays, we produce much the appearance of the first focus, but with two dark shadows on either side of the bright part of the rib; these have been noted by Dr. Pigott (*g*, Fig. 26). The slightest touch of the fine adjustment or prism displaces them, and by a fair appliance of patience, "toying" with the focus and the adjustment of the prism, the image is converted into the appearance at *i*, when the chromatic effects are at their highest; as on either side we have blue and yellow, faint purple and orange, interrupted spaces, crossed by a fine striation, which I believe are the representatives of Dr. Pigott's fine set of beads, if not those brought out on the upper surface in my photographs,* yet caused by the same internal disposition of the parts as in the Lepidoptera waved scales, and giving rise to similar illusory effects. Still, it occurred to me if this were the case, some such structure which is so evident in the Lepidoptera scale as a supporting framework ought to be present. Much time was spent in seeking this, as a friend who seeing me at work naively said, with the head in a bag, as a black velvet covering was so arranged as to shut off all extraneous light from the stage of the microscope, and made to envelop the head; for without such help, and which was constantly used in these examinations, I could not satisfy myself of the reality of Fig. 26, *h*. Fearful prejudice towards this view might influence the interpretation, after being well seen the slide and prism were shifted, and the scale examined at another time with similar success. If the daylight were not very bright, the transverse markings or bars were not seen with sufficient clearness to draw them with the camera lucida, which has been used for all the figures. It is here that monochromatic light, employed after the method of Count Castracane, would, it is deemed, be highly advantageous.

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* 'M. M. Journal,' No. XXI., p. 125.

† Ibid., No. XIII., Plate XXXVII.

These are some of the appearances seen under varying arrangements, and have been made the subject of the Fig. 26, as they are not generally given by others, and may help towards a better understanding of the nature of the scale, and its similarity to the wavy scales of the Lepidoptera. The centre portion of the Fig. 26 represents the optician's view; and here an achromatic condenser was employed, because it brought out the (faintly seen) oblique lines in many parts. This view, so valuable to the optician, I have never regarded, since attempting to photograph the scale long since, as any indication of the real structure; and I should scarcely have dared to figure it, after the beautiful drawings by the late Richard Beck, and the splendid photographs of Dr. Woodward, save, as they are so well known to microscopists, such a figure might, if placed in the centre of the others, tend to the knowledge of the general structure, and facilitate the recognition of the different views given. I may here mention that the scales were examined as opaque objects

* 'M. M. Journal,' No. XX., p. 67, and No. XXIII., p. 261.

with the parabolic condenser, but without apparent advantage in any respect.

It will be gathered from the foregoing and the figures that, like some others (Drs. Pigott and Woodward, &c.), the spines —"notes"!! are not regarded as having any existence as separable bodies, but as due to the refractive nature of the rib at that part, its thickness and solidity, and the direction of the incident light, which opticians know so well how to arrange to the greatest advantage in testing the general "performance" of their objectives—a charming object, doubtless, yet not the whole truth! To quote the words of one of our most skilled observers, the late Richard Beck, when concluding his paper on the photographic appearance of the section of the bossed tumbler, "How can any reasoning be sound when based merely on the appearances of the markings under the microscope, which, as I have endeavoured to show, may be entirely due to the peculiarity of the illumination, and may give not the least indication whatever of the true structure?"*

Nor are Dr. Pigott's views considered as any way indicative of the correct structure of the scale. The beads are regarded as marked optical effects of refraction and interference where the junctions of the longitudinal "ribs" by transverse and vertical septa take place with the opposite membrane, by which we obtain, with the assistance of the oblique attachments, the joint effect of short rods applied to the long ones, and hence illusory, an opinion largely shared by others. In relation to which, I may cite the optical effects procured by crossed glass cylinders, shown so beautifully in Mr. Hennah's photographs,† and which he very kindly sent me. The pseudo-beads are so well represented as real beaded structure, that the appearance would puzzle the most practised eye, and prove how necessary to be guarded in the term beads as components or definite parts of minute structure.‡

Amongst other experiments, an attempt was made, in a rough way, to try and split the scales of the wing of *Pontia brassica.* It was cemented on one side to a glass slide by coloured turpentine cement; then the wing was suddenly torn from the glass, trusting to split some of the scales into thin layers. The scales were left entire. The adherent scales were now subjected to the same violent treatment, by attaching a slide to their exposed surfaces, but from the scale being rendered so transparent by the cement, it was uncertain whether one or two membranes were under view, though evidently some were torn apart; nor was it possible to find with the necessary certainty the corresponding portion of the scale on the opposite glass. Perhaps if tried using only a few scales on a thinly-varnished slide, employing a solution of wax in benzole or chloroform, and covering them with a similarly-prepared stout cover; when separated by force, the scales might be split. This is only a suggestion arising from the previous experiment.

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* 'Intellectual Observer,' vol. vii., p. 95.

† See Report of Proceedings of Societies, M. M. Journ.,' No. XXVIII., p. 195.

‡ Several years since I made photographs of spun-glass hair cut into lengths, then laid on thin glass covers, and attached to them by heat only; next arranged so as to cross or rotate over each other, either with the little rods touching, or with one set resting on the free surface of the other thin cover, or with the free surfaces of both covers in contact. The effects occasioned by interference were highly curious and instructive. Unfortunately, the prints have been mislaid, or they should have been added to the others.

The examinations have been most fruitful on highly-dried or old specimens from hot climates, when anatomized scales were sought. The torrefying alluded to in the previous part has been managed in the following way:—A clean cover had some scales spread out on the centre and examined to see if it contained both the simple and wavy kinds; then covered by a rather smaller thin cover, and both carefully placed on a flat thin piece of iron plate (the iron frame of the large linen-covered buttons answered well). This was held by the forceps at one side, and gradually introduced at its edge into the flame of a spirit-lamp. In a short time the scales were seen to suddenly change colour, and become almost lost to the naked eye. At this moment the support was withdrawn from the flame, but kept at a greater distance from the source of heat, to thoroughly dry the scales. Without the precaution of covering the scales by a second thin glass, they were generally found so contorted as to be useless. Much care is required, or they become fused. The ribs sometimes separated unequally, the interspaces often giving rise to the optical effect of the "notes"!! (*vide* Fig. 18); others shrivelled in various directions, and produced, with some illuminations, most charming chromatic effects; others appeared melted on to the surface, so that a needle could be made to divide them or traverse them in any direction, without displacing the scale. In some, nothing could exceed the beauty of the illusory beaded appearance, both longitudinal and oblique. An attempt has been made to figure the effect (Figs. 13 to 19); and in others the transparent membrane was shown with a portion of the framework attached. On bruising a thoroughly-roasted scale, *there was no evidence whatever of any beads being in or separable from the scales.* The particles of pigment that became detached in every case, most likely from the pigmentary deposit, were very irregular in size and shape (*vide* Fig. 8, from an untorrefied scale).

As regards the nature of the pigment, so called, it is feared the views now offered may not quite correspond with the usually-received opinions. A careful examination with reagents is needed. I have not been able to separate it in quantity sufficient for this purpose, though my friend, Dr. Southby, writes me from Italy, where the Humming-bird Sphinx Moth (*Macroglossa stellatarum*) was plentiful, that he had been enabled to displace it from the surface of the *recent* scale, so as to denude the ribs. Fig. 32 accompanied his remarks of date January 1, 1871.* This would place a pigmentary deposit outside the scale, and this portion I feel disposed to regard either as an exudation of the material within, through the scale membranes, or as the remains of the moisture with which the wings are clothed at the time of emergence from the chrysalis state, rather than as possessing any cellular structure outside the scale. Hence the term here, "pigment cells," seems to be objectionable. Where it existed in a finely granular condition within the substance of the scale, or on the boundaries of the areas produced by the framework, the term "cell" seems less suited; but when in particular spots, or patches of any size, it may seem more applicable, though by transmitted light it becomes most difficult to determine what is due to interference and what to accumulation of coloured material. By the term "pigment cells" we virtually admit their cellular nature; thus it seems open to objection, seeing the term beads is also *sub judice*. Perhaps it would be better to speak of pigment granules where they can be seen as so many separate fine dark or coloured specks in the membranes and edges of the framework of the dark or coloured scales, and pigmentary deposit where a coloured irregular layer can be found in or on the normal free surfaces. Mr. McIntire, in his correspondence, which I take the liberty to quote, suggests "this material never thoroughly dries, and rough usage would modify its appearance": hence perhaps it could be better studied as an opaque object, though a very tedious process with high powers; certainly torrefaction does not much aid in its displacement, and finding this, I hoped more from the use of strong sulphuric and nitric acids, but was disappointed: other reagents may eventually aid in its study, for optically it is feared we shall not arrive at anything very definite. For those scales which are nearly transparent, and where pigment, as such, not necessarily of a dark colour, exists in a highly granular condition, I would suggest that it should in such scales pass by the name of pale granular pigment, or short, pale granules, and where external, pale granular deposit, which would embrace those scales which are of a silvery or pearly-opaque aspect, or which may be of a dead white, varying to any tint of a light colour, even to brick red. This would not bind us to any theory, and give more decision to our studies, yet quite open to improvements.

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* "I enclose you a pencil sketch of part of a scale of the Humming-bird Sphinx. I took the scales with my finger made quite dry from the living insect, then placed them on a clean piece of glass, and took another piece and pressed it upon the first, and gave it a roughish slide on the other; then examined the ill-used scales with my $\frac{1}{5}$th object-glass, corrected for uncovered objects. The scale from which I took the sketch was from the first, therefore the surface seen was the upper surface: you will see that the rough treatment has luckily abraded the cuticle, if we may so call it, on both sides, leaving the internal bars in places quite clean. The under side is the same as the upper as seen in another scale." My views make the outer membrane or surface as the most transparent, and the inner as the chief pigmentary membrane.

It is at the moment of emergence from the chrysalis the study of this substance may be best undertaken, when perhaps the external deposit may be made to adhere to the slide or thin cover. Or the scale from the living insect taken for the examination of the granules within the substance. Possibly it is in the nature of the pigment we may find the function of the scale, if endowed with the property previously suggested.

Whether individually and collectively the pigmented scales may share in the inherent power of " mimicry " described by Bates and Wallace, by which the bearer establishes a close but false resemblance to some of the creatures of its own kind, to avoid personal detection, or to a different order or division of the organic kingdom, as in the simulation of leaves by the leaf butterfly, not only in the healthy condition, but also in " every stage of decay, blotched, mildewed, pierced with holes, and in many cases irregularly covered with powdery black dots, gathered into patches and spots, so closely resembling the various kinds of minute fungi that grow on dead leaves, that it is impossible to avoid thinking at first sight that the butterflies themselves have been attached by real fungi ;*—

Or whether, as in the Heliconidæ, any power be shared by them in common with other organs, of furnishing a disagreeable odour, are questions bearing on the subject, but which, for want of specimens, have not been examined ;—

Or again, whether the scales harmonizing beauty and utility may not more directly than is generally suspected enter into relationship with the little amatory episodes of these insect creatures, by adding increased brilliancy and splendour to the already highly-attractive nuptial vestments of both sexes ;—

Or whether they may be individually or collectively wanting in these endowments, and only modified by the local influences of climate or food, must not be overlooked in their study. Of the variability in *Kallima paralekta*, the under surface is described as so " variable in colour, that out of fifty specimens no two can be found exactly alike, but every one of them will be of some shade of ash or brown or ochre, such as we find among dead, dry, or decaying leaves."

My friend Mr. McIntire, who has given us such valuable particulars of the life and habits of some of the Thysanuradeæ, points out that the change of skin takes place at the time when the scales are in all stages of development, that the growth of the scales is arrested, that they dry up and form a somewhat thick layer of elastic corrugated plates on the delicate skin of the owner ; whereas

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* See also Wallace's " Natural Selection," " Malay Archipelago."

I suspect them to retain their freshness and be capable of effecting such changes on the semi-solid material within, as shall keep the scale in its normal state, especially as relates to the pigmented scales in Lepidoptera. Mr. Wenham notices the scales of Lepidocyrtus are limp as wet paper, and certainly it is difficult to unbend them without damage when folded.

I would willingly cede these points, was it not deemed that the pigmented scales require a fuller examination than they have yet received at our hands.

How much of the iridescence of the scale may be due to light reflected from a finely-ribbed surface, or from interference and diffraction in its passage through irregularly-refracting portions, occasioned by the inner framework, or to the fine pigment granules in the substance of the scale, or to the pigmentary granular deposit on the free surface, is doubtful; but we must not overlook the fact that where the pigmentary layer has been accidentally or purposely removed, the chromatic effects are yet very perfect under oblique illumination. It is assumed the pigment material largely determines the general colour of the scale, as yellow, green, brown, blues, reds, &c., of all shades, and the pearly or opaque white by reflected light, perhaps by absorption.

For it was noticed, heat in charring the scale altered its colour to the naked eye, most completely in the very iridescent scales, while under the microscope their structure was not proportionately changed, unless the torrefying had been carried to extremes when parts were often displaced.

How much of the colour may be due to interference or the passage of the light through the object traversing substances capable of affecting the velocities, bending them out of their course, more or less diffracting or breaking them up into prismatic rays, and these again suffering refraction and reflexion in various ways; to at last meet with rays of certain velocities, which either swell their amount of colour, or interfere by want of harmony in their undulations, and either reduce them or modify them, so as to furnish several compound colours in all parts of the object, of more or less corresponding power over the original light, and with interference shadows in addition, is a question open to considerable doubt, if not defying human skill.

And when the phenomena of colour in its complementary characters embrace more than two colours, due in part to the nature of the object and in part to the final corrections given to the objective by the optician, the subject becomes much confused by furnishing a mixture of interference spectra, very charming to the eye, as in Figs. 5 and 26 *i*, but useless in the analysis of structure. Yet if the adjacent parts be not sacrificed in definition, an additional aid may be found for increasing our knowledge of intimate structure, as with polarized light, though, if we disregard the appearances produced by other methods of observation and illumination, which furnish a better clue to the real structure, *without marked chromatic effects*, we shall be in constant danger of accepting illusory appearances.

To the terms " ribs," " cross-bars," at first sight there may appear some objection; but when the figures are examined where the rib and its attachments are seen together stripped from the scale (Fig. 2), the terms seem to me less objectionable than " corrugations" " folds," or " striæ." Now, Mr. Slack sees in the ribs " only corrugations or wrinkles" in the butterfly scales, and I think Mr. McIntire and others prefer these terms to " ribs"; hence it is with diffidence the former are employed, for terms used to convey appearances under the microscope are seldom quite satisfactory. Mr. Slack says, " the beads more or less distinct, or coalescent, as the case may be, I take to be formed by exudations, in drops, from the membranes, consolidating, so far as they do consolidate, in a definite form."* This view appears open to considerable doubt, though a kind of compromise of different theories and contrary to the one adopted in this article, which is perhaps more advanced in particulars than suggested by my friend Dr. Woodward in the recent pages of the 'Monthly Microscopical Journal,' No. XXVIII., p. 158, or than pointed out by that careful observer Mr. McIntire. The inner membrane appears slightly extensible, the ribs can be compressed out of shape in some scales, and in none did they appear to me hollow, as Dr. Bowerbank suggests: a communication through the quill to the inner surfaces is suspected to exist in all scales, and in relation with the membranes of the wing or dermic support.

Whether the butterfly would show any change in the general colouring of the wing, by the transmission of feeble electric shocks through the living insect, is doubtful, though perhaps worth an experiment It will be seen that I am disposed to give to these flattened bladder-like bodies some function, higher than is usually supposed, though the transition from hairs "protective" and " ornamental" is so gradual towards their own varied shape and substance, that they appear more naturally to accord with those ordinary dermic structures. Possibly they may be expended tegumentary organs, which passed their active phase in the chrysalis state, and merely preserved a common attachment upon emerging from this condition. Mr. McIntire points out † the moment they become external appendages they cease to grow; yet does it follow that all changes in the material within the membranes of a semi-solid greasy nature are checked, or are not kept in a normal condition for the benefit of the scale? To some alteration in this material the pigment seems due, and should be referred. It is a point for further investigation and quite open to inquiry.*

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* 'Student,' No. 1, p. 54.

† 'M. M. Journal,' No. XXV., p. 6.

It seemed to me some attempt might be made on a large scale to ascertain whether if two artificial arrangements based on the figures given of the Lepidoptera scale, which also furnished when charred the appearance of the "notes"!! and of "beads," would, when placed facing each other, furnish an image of beading after the views of Dr. Pigott, when direct sunlight was allowed to traverse them. Hence a large very rude pencil sketch (Fig. 31) was made of Fig. 15; over this was laid a clean piece of glass; the "ribs and cross-bars" were then followed roughly with a composition consisting of mastic dissolved in chloroform and just tinged with aureolin (ground for oil painting), and laid on very thickly in the course of the ribs, lightly over the bars. When dry the plate was reversed, and on this was placed another piece of glass; the ribbings and cross-bars showing through, were then followed in the same manner with a sable pencil charged with a mixture of mastic, wax, and chloroform, untinged and laid on thickly over the ribs, less so over the transverse and oblique bars. When dry these glasses were placed opposite each other at apertures cut in a narrow box, all the light being excluded from beyond the outer edges of the figures, and then held up to sunlight, the image being received on glass dulled (by amber varnish used cold and allowed to chill), placed at variable distances. After a little patience and manœuvring a beautiful dotted or beaded image was shown on the glass, *all trace of ribs and cross-bars had disappeared.* This was several times shown to others, and finally received on a sensitized collodion plate which furnished the negative from which the photograph (Fig. 27) is printed: the lenses were removed from the camera, so that the effect of diffused light through the transparent spaces has given a rather weak image.

The camera was shifted, the lenses inserted ($\frac{1}{4}$ plate, Voightlander) and eight negatives were taken of different appearances; unfortunately in varnishing them the collodion cracked, and too sadly marred the image to be of any use, but the figures of three are added, as also the coarse pencil sketch of Fig. 15. In Fig. 28 a resemblance exists to one view of *Degeeria domestica.* In Fig. 29 several bright-beaded spots will be noticed on the "ribs" and their generally beaded aspect; a dark shadow between the "ribs" and their coalescence.

In Fig. 30, to the left of the figure in the negative are two lines composed of *distinct* small dark spots ("beads"?), but so much more delicate than the rest of the image, that they are almost lost by printing the detail of the other parts, which, before injury by the action of the varnish on an old collodion, gave a medium image between Figs. 28 and 29, partaking of both. Of course the representation was too rude to positively assert that the beaded structure of the insect scale arises from interference and diffraction, &c.; but it has its *value* as bearing on the opinions and figures contained in this imperfect sketch.

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* *Vide* Watson "On Plumules," 'M. M. Journal,' No. VIII., p. 77, and No. XII.

Photography would have been used more largely, had I not learnt from experience that some of the appearances would not have been easy to record without very considerable trouble, especially as the season was not sufficiently advanced to undertake the experiment with either comfort or certainty.

Every care has been taken to render the objects as seen, but to obtain the prismatic effects with all their charm and vigour was hopeless. To quote Mr. Slack's words, "It is only by combining *all* the appearances which seem to give real information, that we can expect to arrive at a true conception of structure;" as aids therefore to others, rather than as dogmatic assertions, it is hoped the foregoing remarks will be received by the Fellows of the Society, to whom I beg to offer every apology for such "dry as dust" details, in venturing to attempt some explanation of the wondrous contrivances, endowed by the Creator with the property that sheds a lustre, both on the gay and gaudy visitor of the hour, or the silent and agile tenant of the dreary cellar.

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